First validation of AIRS, MOPITT and IASI CO total column over severe wildfires: implications for top-down emission estimates.

Leonid Yurganov, JCET/University of Maryland Baltimore County,

in collaboration with V. Rakitin, A. Dzhola, E. Fokeeva, G. Gorchakov, E. Grechko, A. Karpov, , E. Semutnikova, R. Shumsky (IAP, Russia), T. August (Germany), M. George (OIT, France), L. Ott (GSFC), S. Hannon, and L. Strow (UMBC).

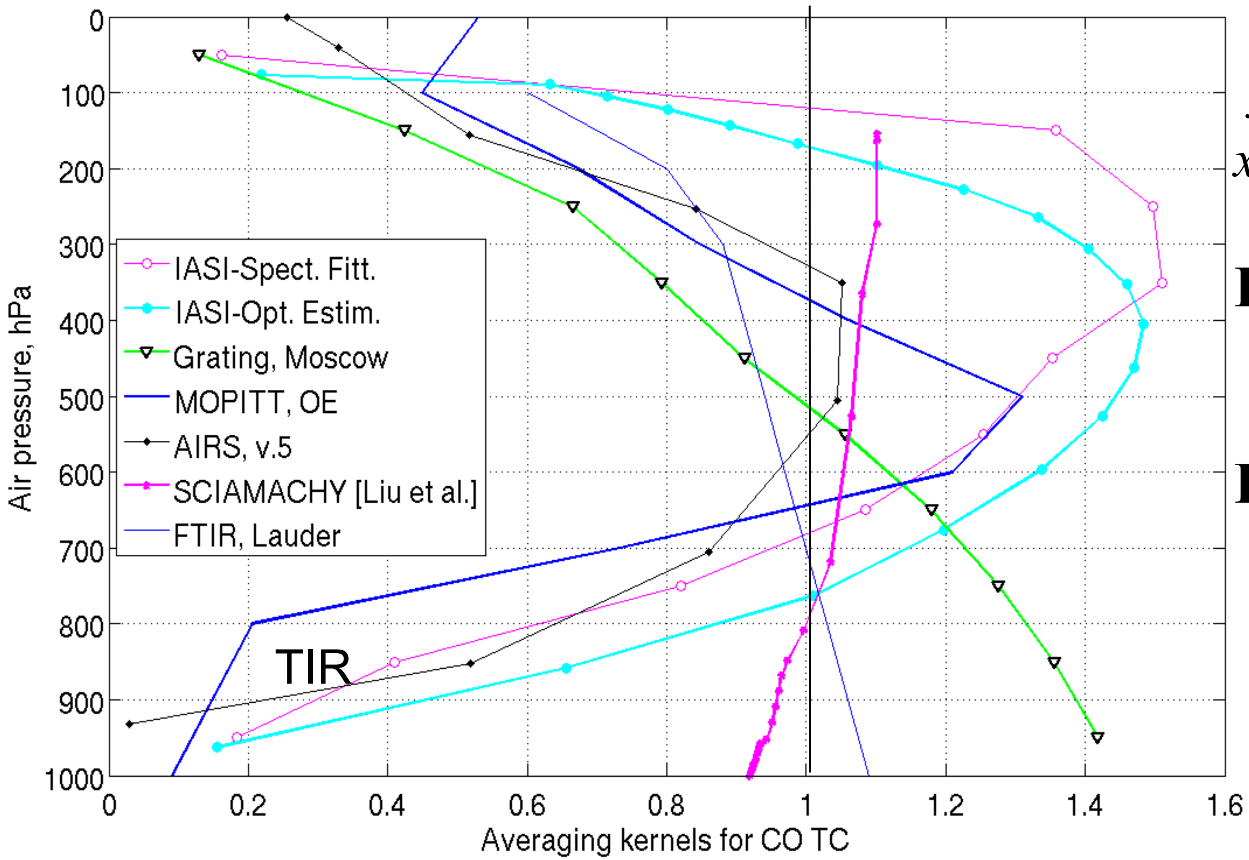
This report is based on a paper in ***Atmospheric Chemistry and Physics*** (Yurganov et al., 2011): "*Satellite- and ground-based CO total column observations over 2010 Russian fires: accuracy of top-down estimates based on thermal IR satellite data*".

NASA Sounder Science Team Meeting, 9 November, 2011.

OUTLINE

- Vertical sensitivity: TIR vs NIR satellites, nadir vs solar tracking from the ground.
- Validation-1 and Validation-2 for Total Column
- Validation-2 over Russia before fires.
- A case of wildfires in European Russia in summer of 2010: <u>underestimation</u>
- Importance of this error for top-down estimates of emission and comparison with bottom-up inventories

Averaging kernels (AK) for CO Total Column (TC)



According to Clive Rogers,

$x_{ret} = x_a + AK^*(x - x_a)$, where
x_a is a priori, x *is* true profile,
x_{ret} is retrieved profile

If AK = 0, then $x_{ret} = x_a$ (a priori)

If AK = 1, then $x_{ret} = x$ (true)

Validation-1: CO profiles are obtained using aircrafts, <u>convolved</u> with AK, integrated and compared with TC retrievals from satellites. This validation is mostly important for algorithm developers.

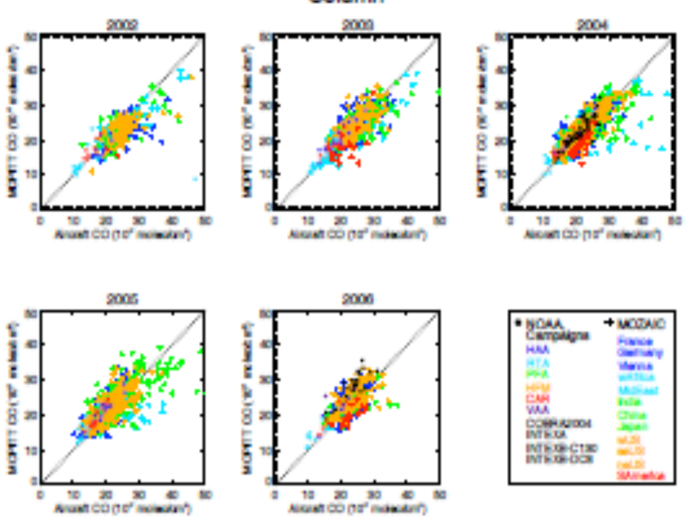
Validation-2: CO TC is measured from the ground using spectrometers with high sensitivity to the boundary layer, and compared with <u>unconvolved</u> retrievals from satellites. This validation is important for data users: they need truth.

Example validation-1. MOPITT v.3, Emmons et al, ACP (2009)

Aircraft data of 22 campaigns and sites are used

Convolved CO vs integrated profiles

1799



A long-term drift of the bias is found

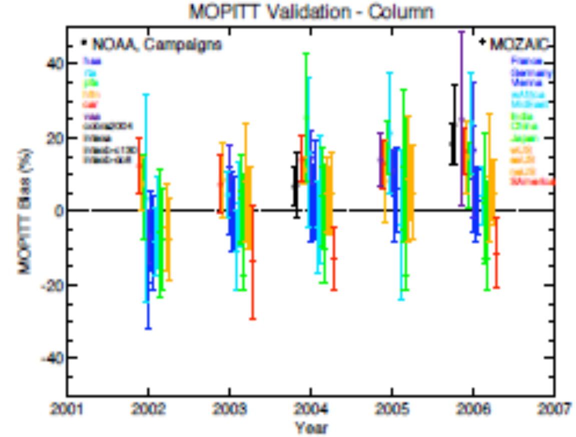
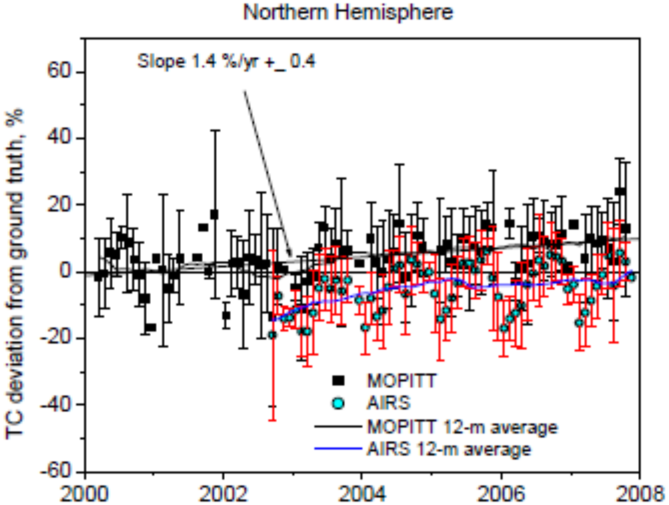


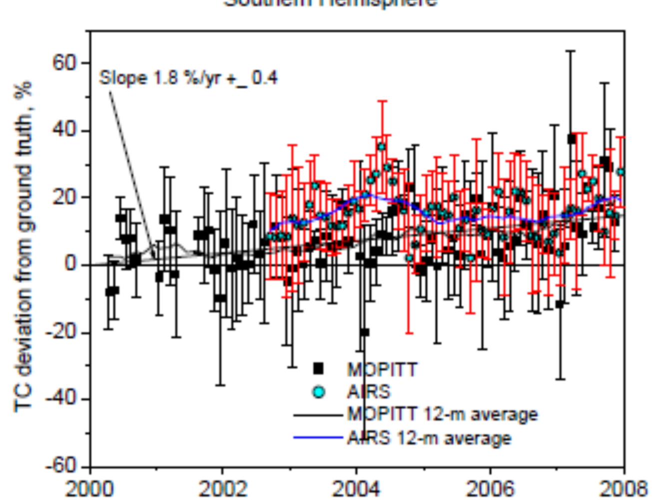
Fig. 4. Bias between MOPITT and aircraft in situ measurements for the column retrieval for each year, sorted by NOAA site, Field Campaign or MOZAIC geographical region. Each symbol and error bar indicates the mean and standard deviation of the biases for each site or region.

Fig. 3. Symbol

Example validation-2. MOPITT v.3, AIRS v.5, Yurganov et al, ACP (2010)

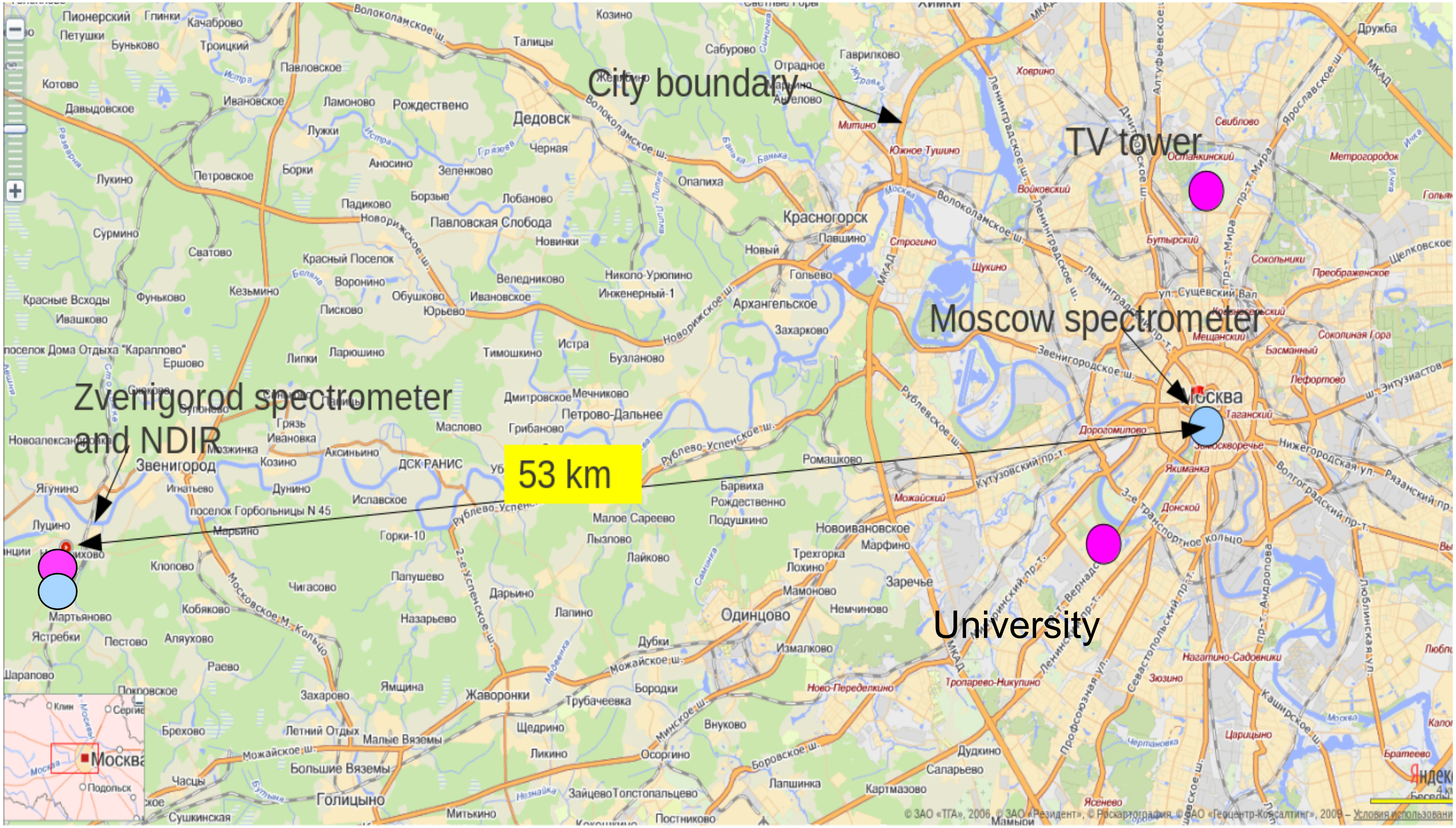
Year-round data from 7 FTIR NDACC sites (5 in NH, 2 in SH) are used





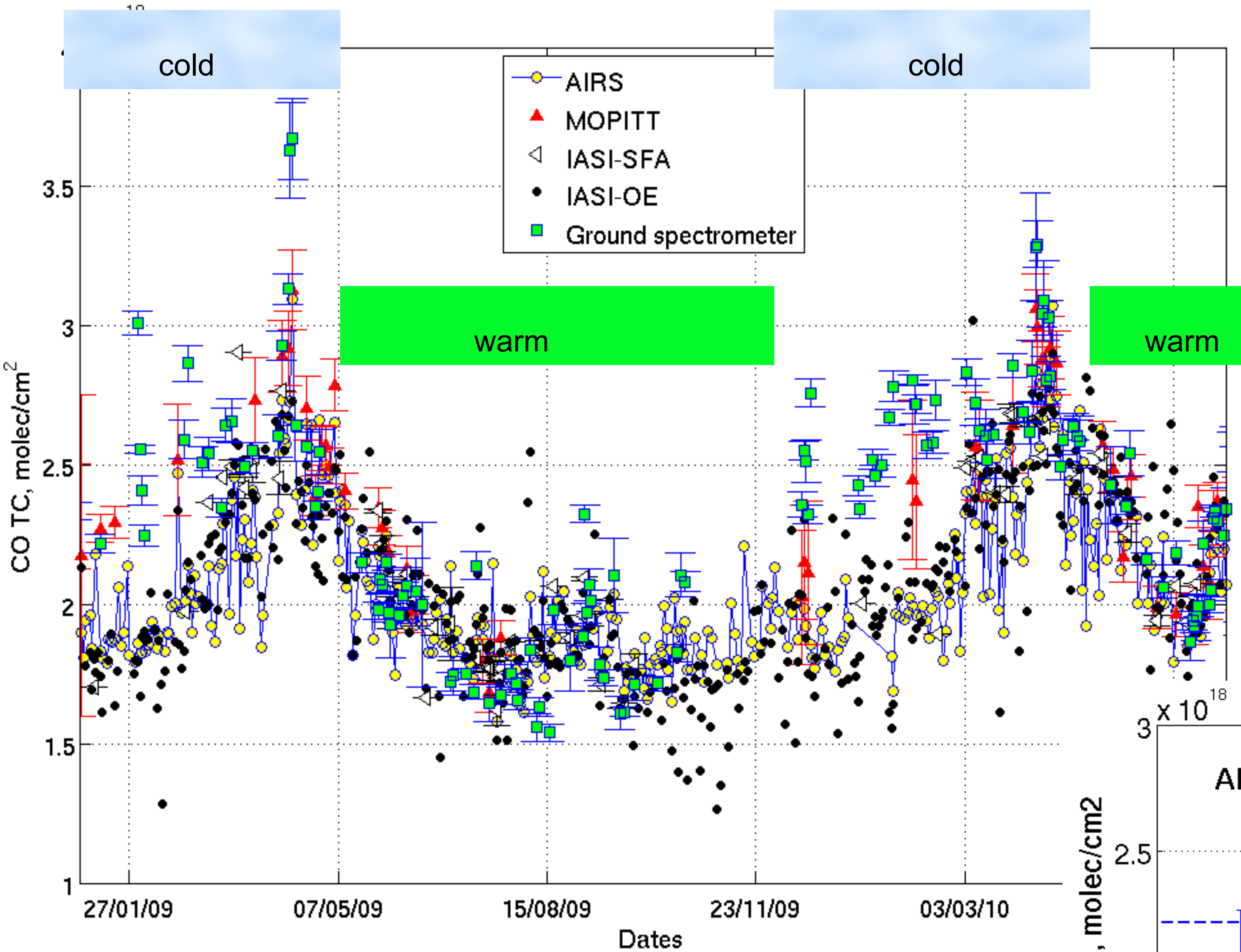
A long-term drift of MOPITT v3 data is found as well.

Locations of observational sites in Russia: TC, local

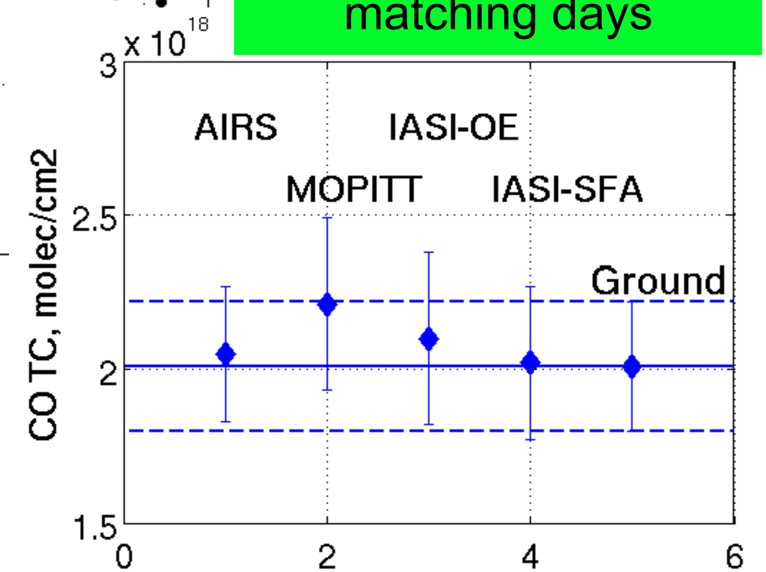


Zvenigorod observatory is a rural site, Moscow spectrometer is in 1 km distance from the Kremlin

Validation-2: 2009-2010 before fires, rural site Zvenigorod



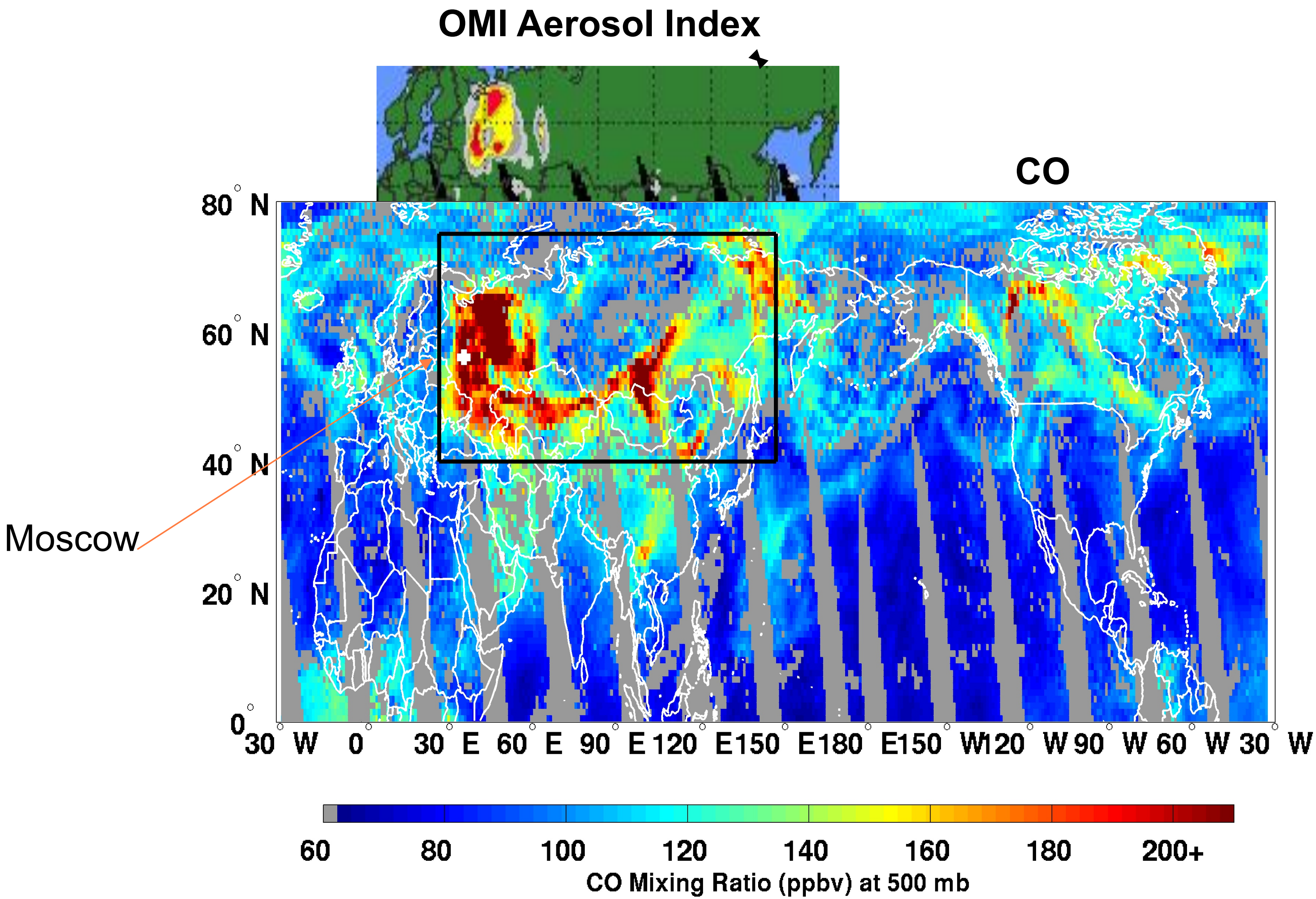
Averages over the warmer periods and STD, matching and not matching days



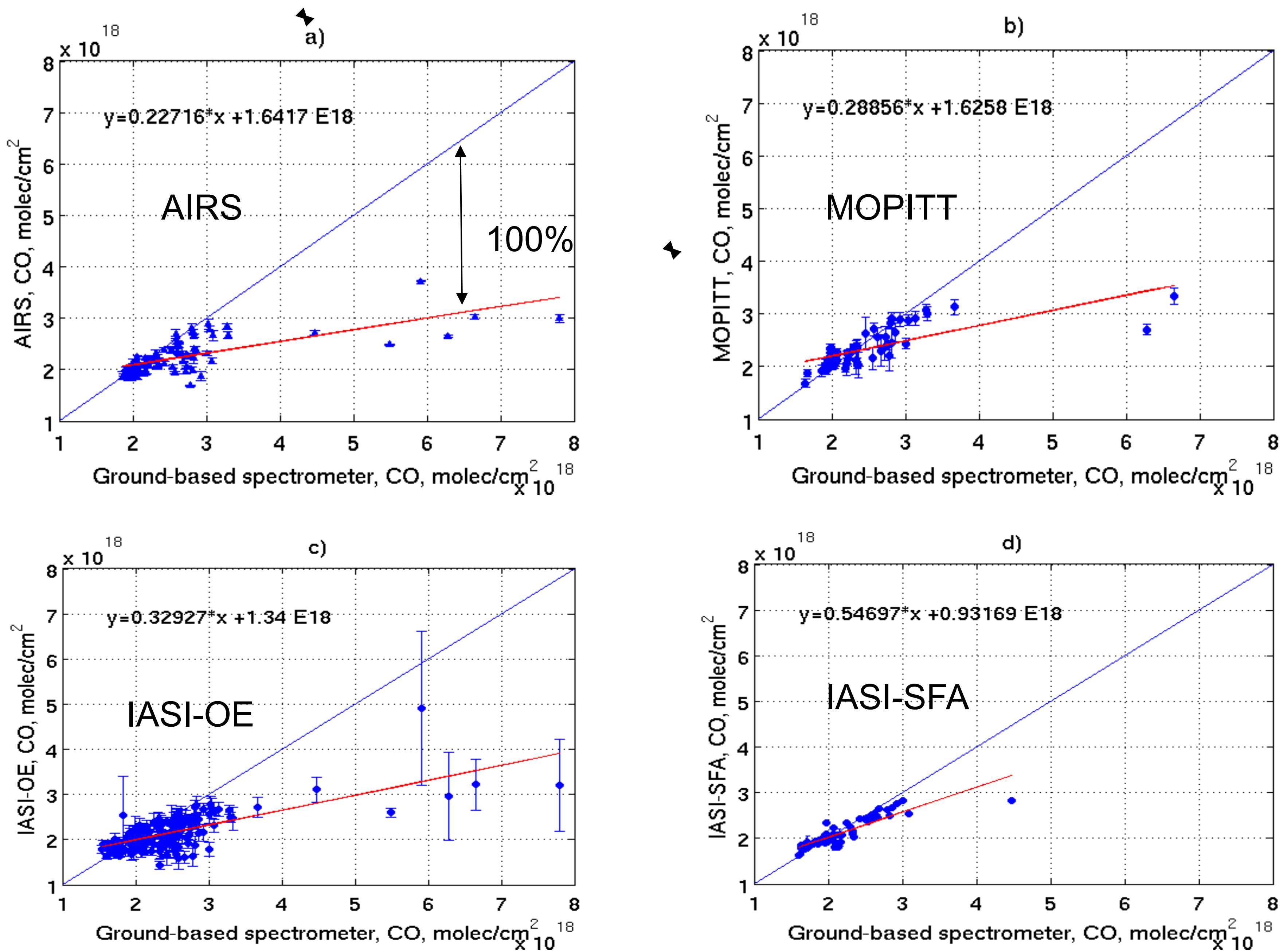
Validation-2 for summer time was successful, bias less than STD (~10%). Winter time is problematic.

Fires started at the end of July

A map for 9 August, 2010. CO mixing ratio at 500 mb according to AIRS V5 and aerosol index according to OMI.



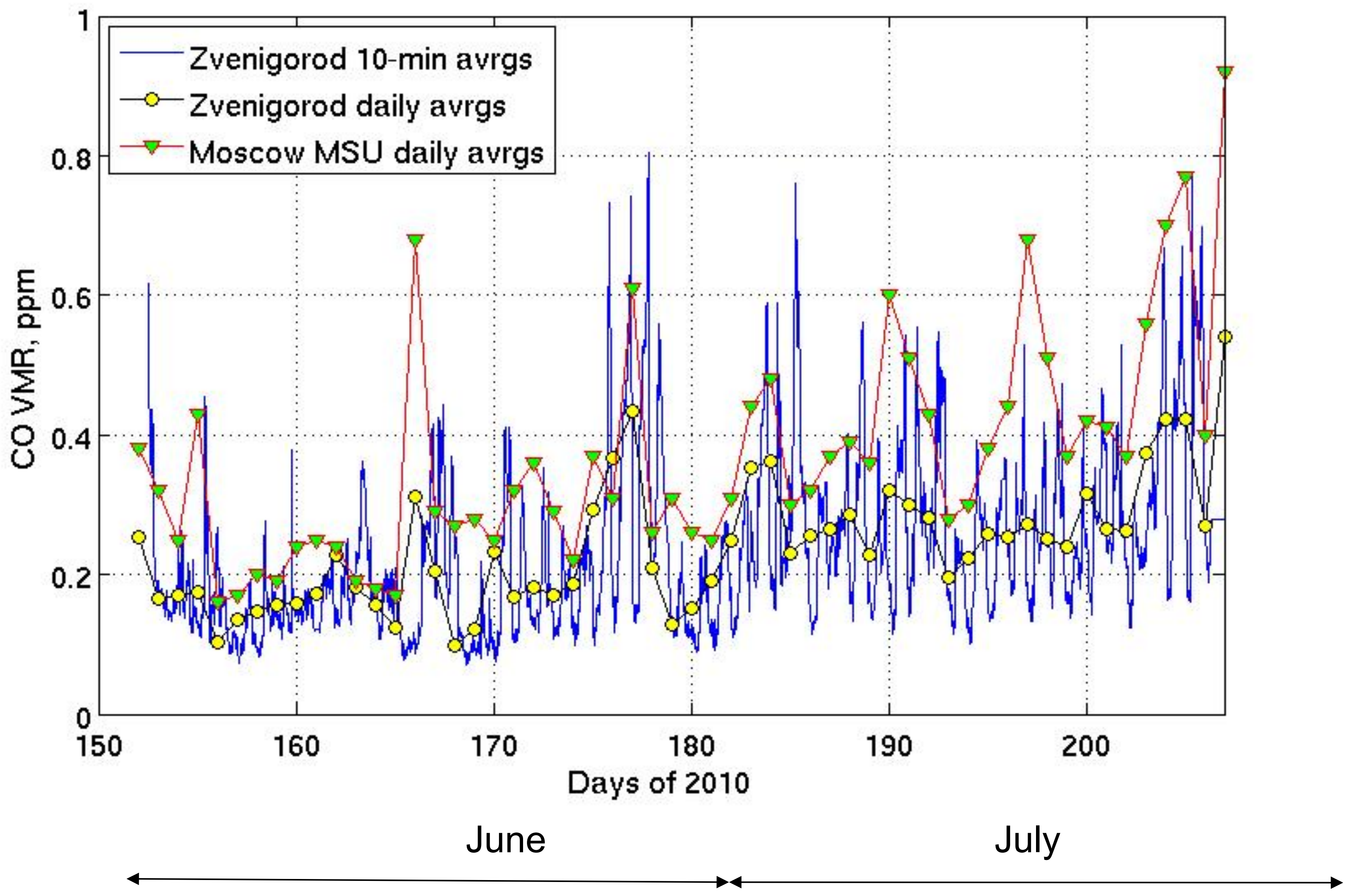
Validation-2 for the entire period, including winter and plume from fires, in Zvenigorod,
~100% underestimation during the fire



In situ CO mixing ratios near the surface in the rural site (Zvenigorod) and in Moscow, University campus.

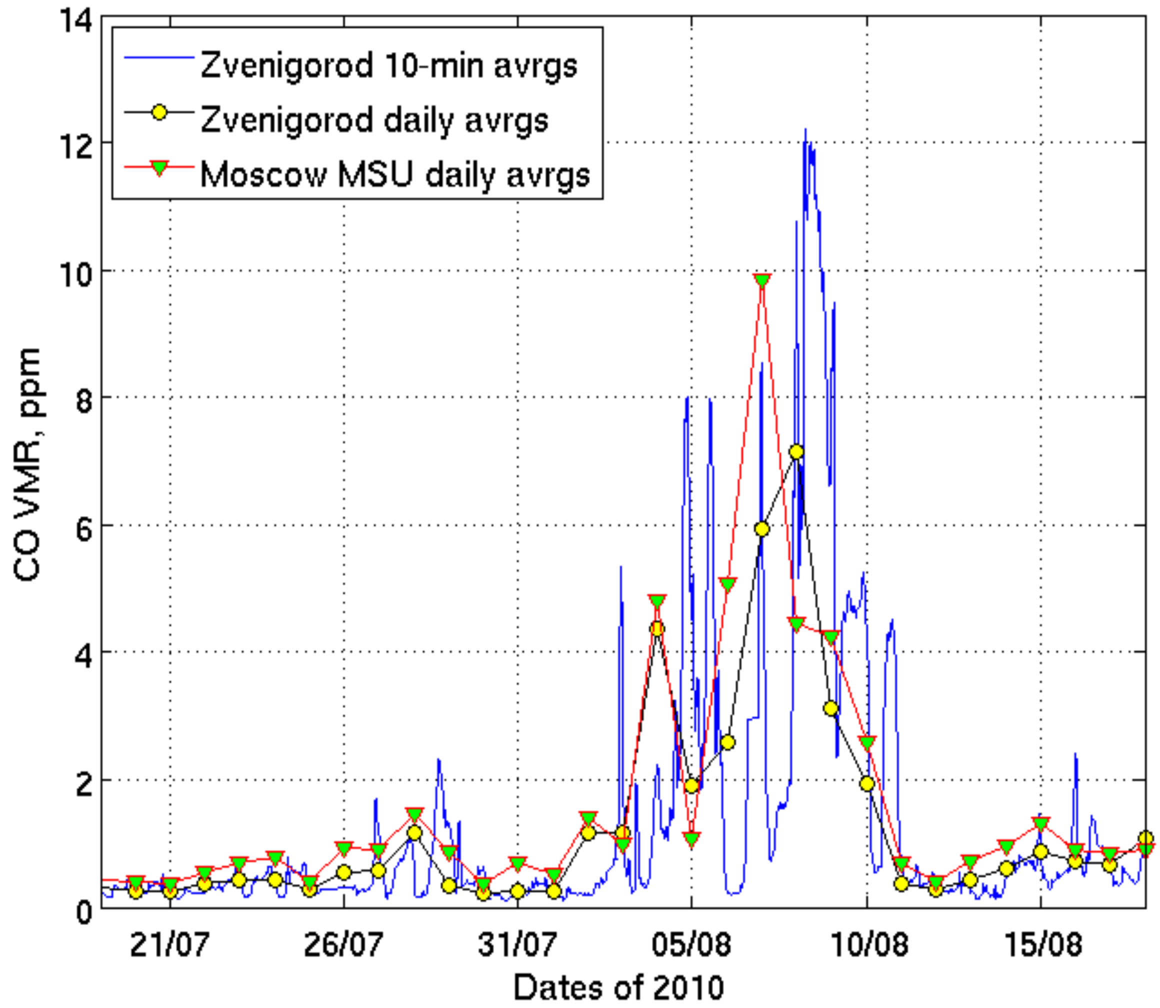
PERIOD BEFORE THE ARRIVAL OF THE PLUME TO MOSCOW

Urban CO has weekly (triangles) and diurnal (not shown) cycles, rural CO has diurnal cycle (blue), but no weekly cycle (yellow circles).



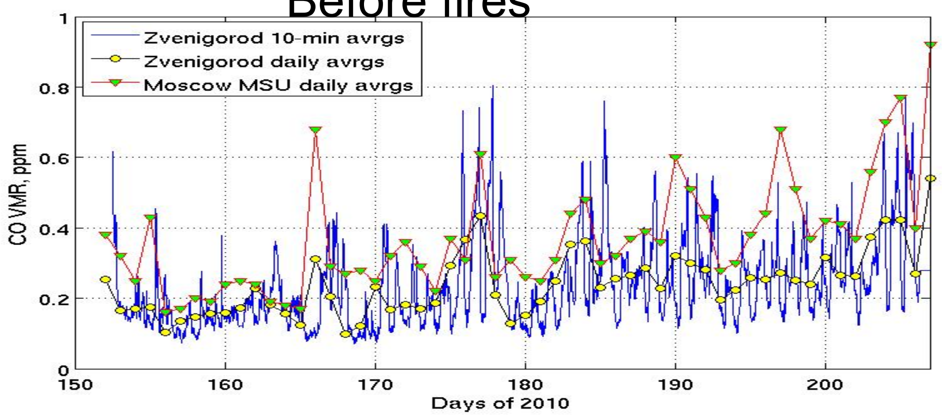
Fires started

In situ CO mixing ratio during the period when the plume covered Moscow (**note a change in the Y-scale)**.



Previous slide

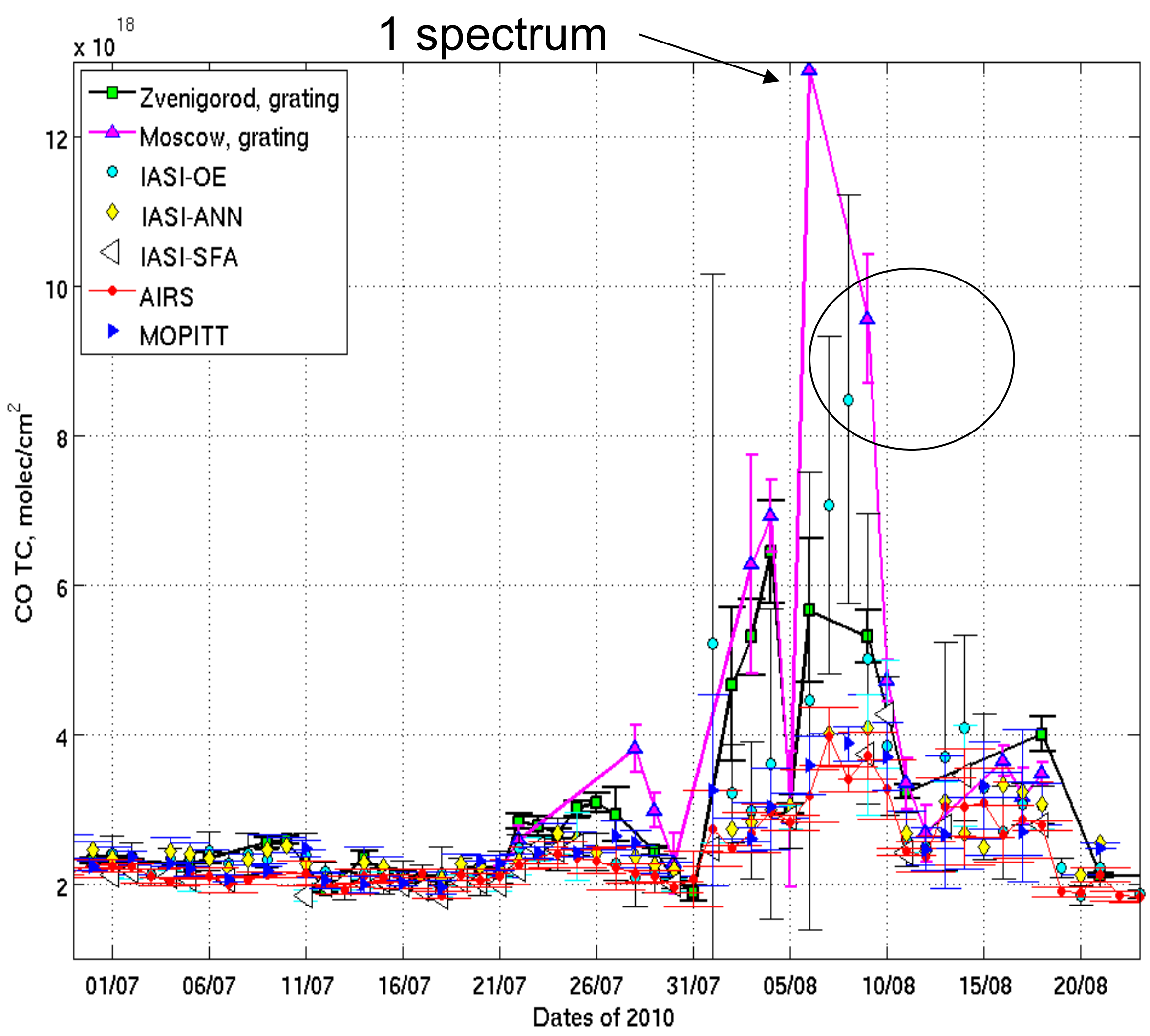
Before fires



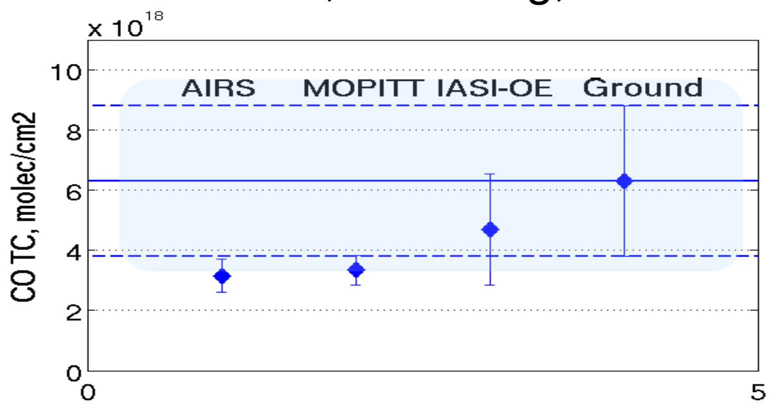
No doubt that between 2 August and 10 August CO from wildfires dominated over the anthropogenic CO, both in rural and urban locations.

Moscow area, the fire period, July – August 2010, CO total columns

CO TC underestimation for TIR sensors sometimes is 2-fold or 3-fold. It is NOT a fault of the algorithm, rather it is explained by physics of radiative transfer through the atmosphere: low sensitivity in the BL.

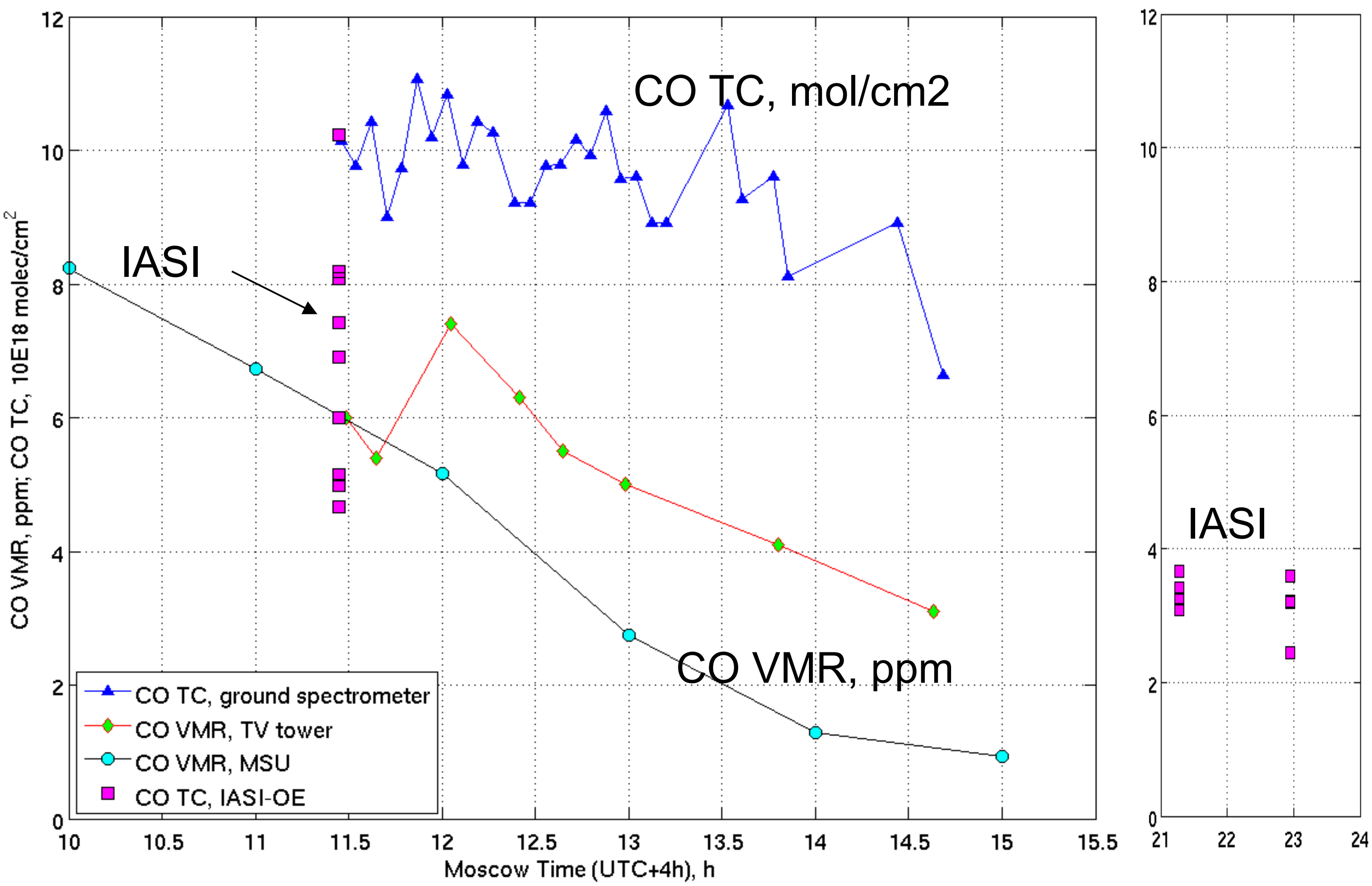


Average TC for Moscow/Zvenigorod area: 2° x 3°, 2 – 9 Aug, 2010.



9 August, 2010, Moscow, two sites of in-situ sampling, ground spectrometer, and IASI-OE, three overpasses

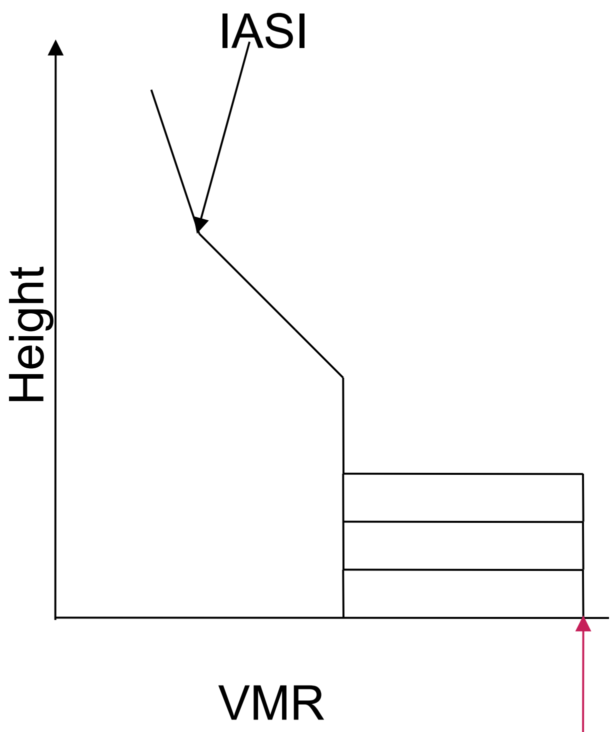
Since 9 August the plume started moving away from Moscow and this was demonstrated by all three kinds of data.



Depth of polluted layer on 9 August 2010

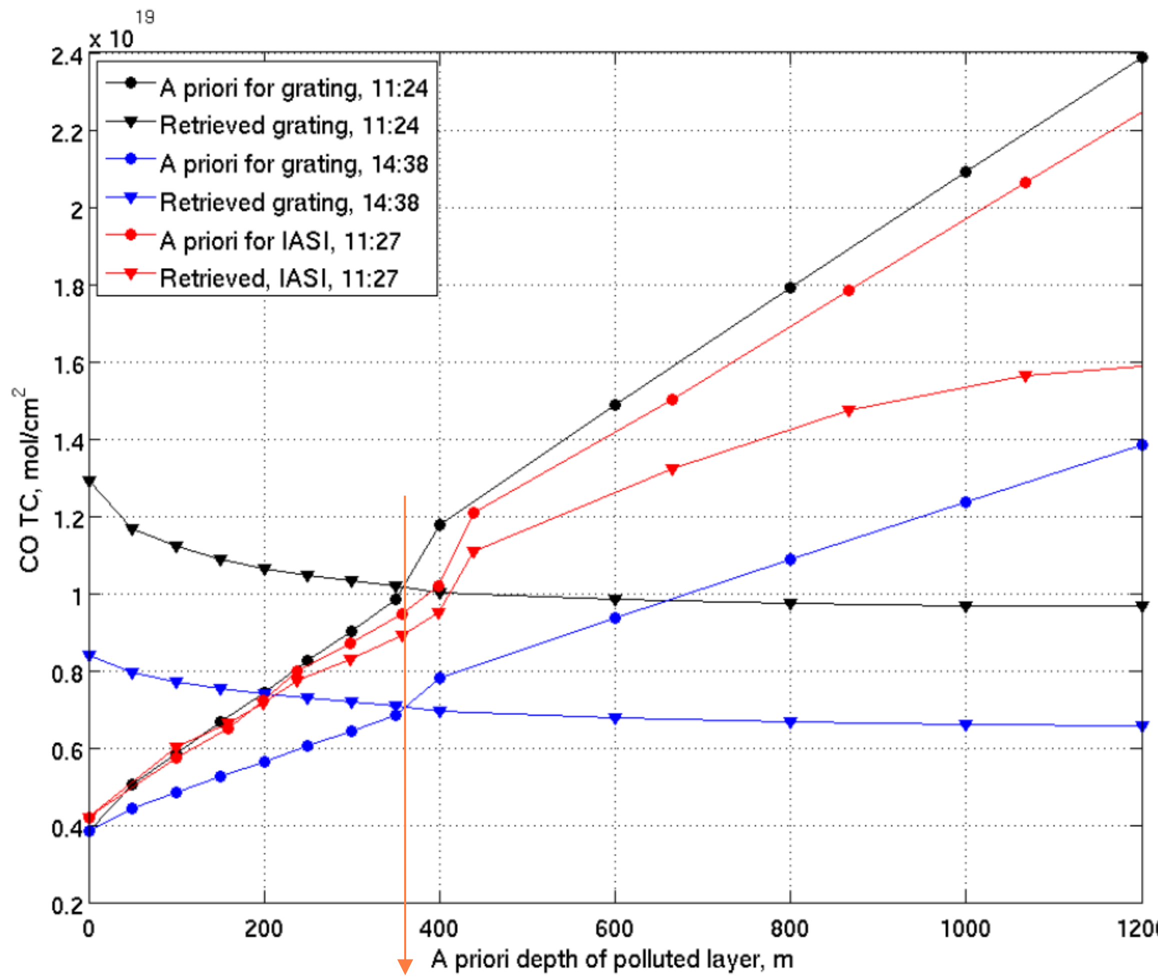
How to estimate this without an aircraft?

The depths of polluted layer for 11:24 and 14:38 were estimated as 360 m



TV tower up to 200 m

+ Spectrum from the ground gives TC CO

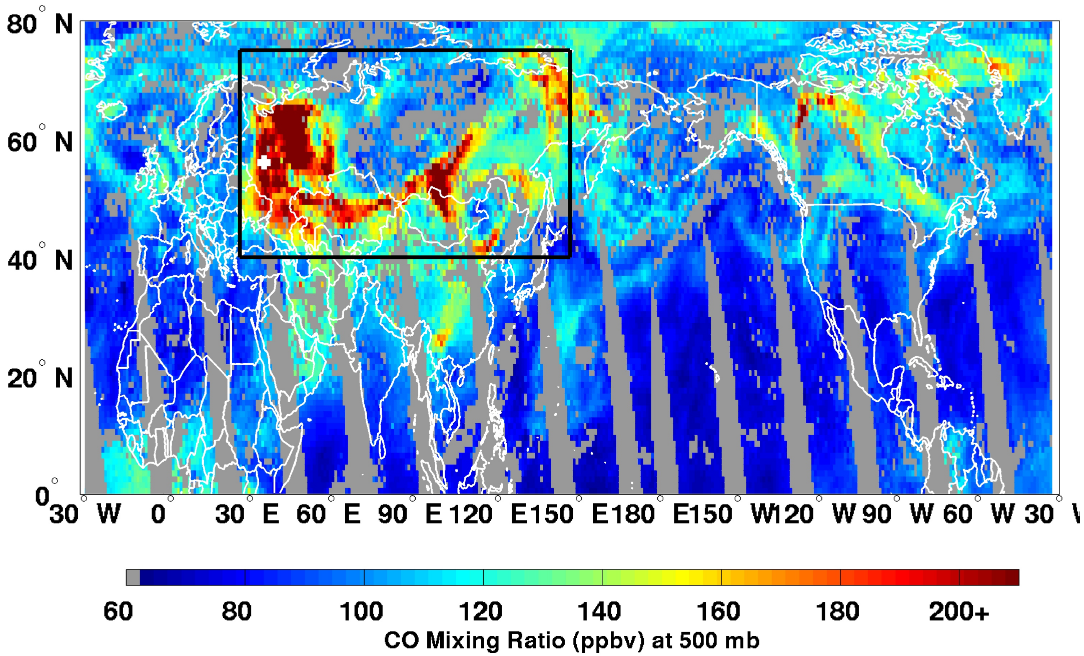


360 m

Results of validation over Moscow area were extrapolated on the entire plume.

Between 2 and 9 August AIRS CO VMR-500 over Moscow was between 150 and 250 ppb

Plume is determined as areas with VMR_500 > 150 ppb (yellow on the map)



CO total mass M was converted into CO emission rate.

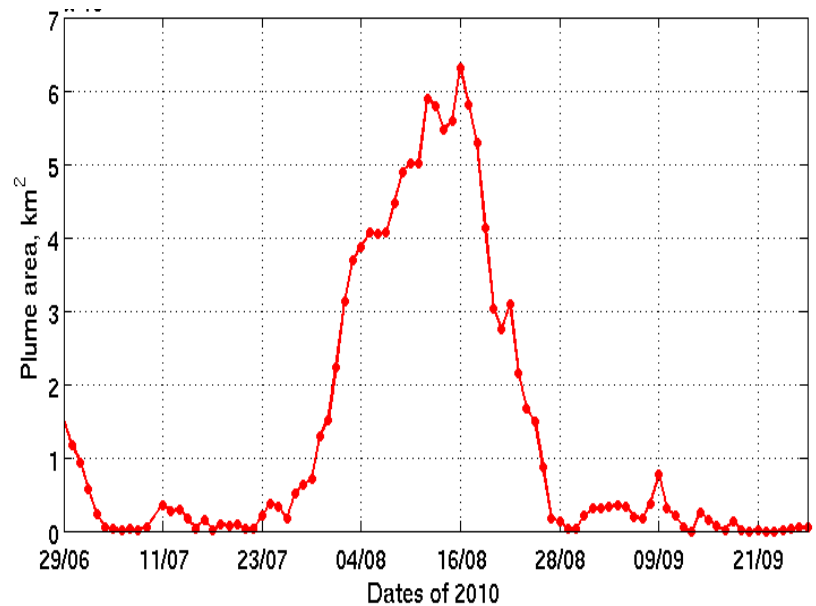
CO emission P in Tg/day:

P = dM/dt + L(OH oxidation) + L(wind removal)

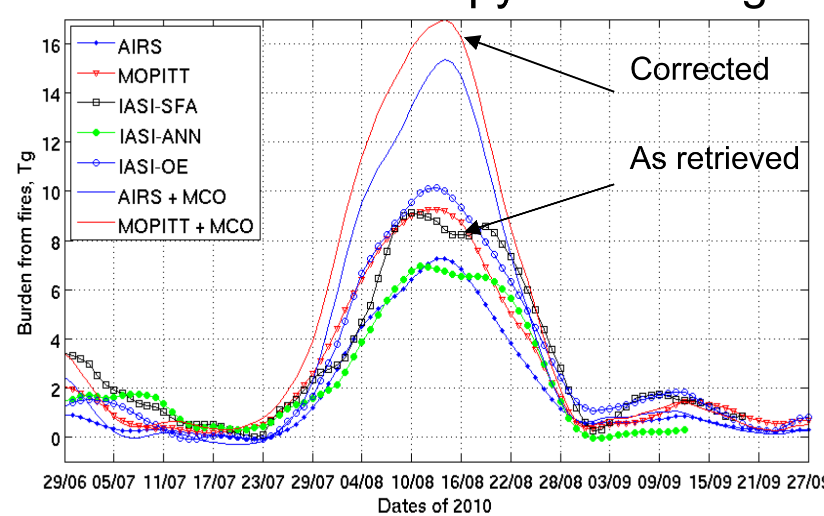
[Spivakovsky et al.]

GEOS-5 CTM

Plume area in mln sq. km



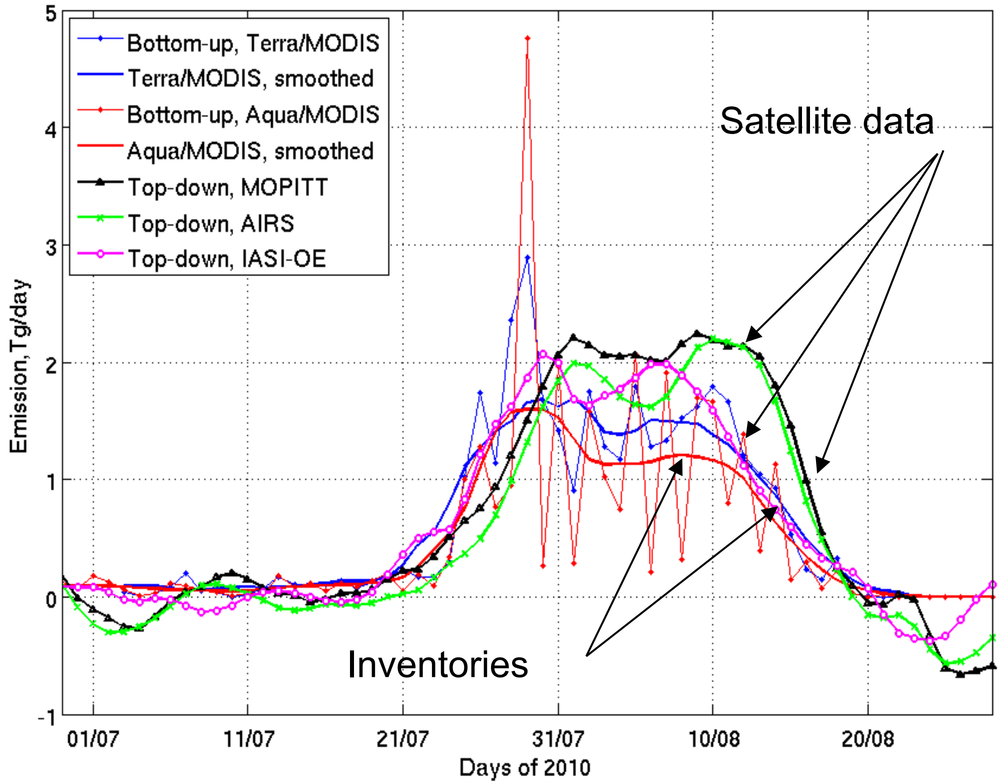
Total mass M of pyro-CO in Tg



Influence of correction on the estimate of emitted CO

Instrum., inventory	Total emission, before correction, Tg	Total emission, after correction, Tg	Ratio
AIRS	16.8	33.7	2.0
MOPITT	22.3	39.6	1.8
IASI-OE	26.2	35.6	1.4
MODIS, Terra	--	***36.1***	--
MODIS, Aqua	--	***29.8***	--

Corrected emissions are compared with inventories obtained by the "Active Fires" procedure (Fokeeva et al, 2011)



Due to correction the emission estimate changes 40 ~ 100% for different instruments

Top-down estimates from satellite data agree with some (NOT ALL) inventories

CONCLUSIONS

1) First validation of TIR instruments over a plume of severe wildfires has shown a significant underestimation of CO TC NOT convolved with averaging kernels. NIR instruments are expected to work better for severe fires.

2) For the Moscow area CO TC for AIRS v5 and MOPITT v4 are 100% and 89% lower than ground truth, IASI-OE is 34% lower than ground truth.

3) The depth of polluted layer over Moscow is estimated as 360 m for August 9, 2010

4) Total emitted CO in Russia after correction (that amounted to 40 ~ 100%) are estimates as 34 – 40 Tg.